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A METHOD

FOR THE

ANALYSIS OF MILK.

BY

E. H. VON BAUMHAUER.

TRANSLATED BY H. CARRINGTON BOLTON, PH.D.

Reprinted from the AMERICAN CHEMIST, *November*, 1876.

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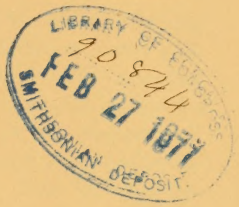

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A METHOD FOR THE ANALYSIS OF MILK.*

(Read at the Buffalo Meeting of the American Association for the Advancement of Science.)

Translated for the Author, by H. Carrington Bolton, Ph.D.

ABOUT ten years ago I published the results of a long series of researches on the composition of cow's milk in the Netherlands, the examination being extended not only to milk in its pure state, as yielded by the cow whether stabled in winter or in the pasture during the summer, but also of the milk furnished to the inhabitants of our large cities. This investigation proved that the only adulteration to which milk is subjected in the Netherlands consists in skimming and dilution with water; but this fraud is sometimes practised on so large a scale that more than half the milk sold is mixed with water, and in order to conceal the blue color produced by diluting milk frequent use was made (in Amsterdam, at least) of water of a dirty yellow hue.

In connection with these investigations, which embraced more than 150 different samples of milk, I devised a new method for the determination of the essential constituents of this liquid, which will be found advantageous both on account of the accuracy of the results and the rapidity of the execution, and is especially commended to chemists who are called upon to testify as experts in legal processes, and to those who have a large number of analyses to make.

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*Dr. Von Baumhauer stated, during the discussion which followed the reading of this paper, "that each milk inspector in Holland is furnished with a lactometer."—TRANSLATOR.

Since the chief alteration to which milk is submitted consists in removing the cream and adding water, it has been supposed that the determination of the proportion of cream by means of the creamometer or the lactoscope, combined with a determination of the density by means of a hydrometer, sufficed to decide with certainty not only whether the milk had been sophisticated, but also to what degree the skimming and dilution had been practised. As to the determination of the specific gravity alone, notwithstanding that in certain countries this is the method of testing exclusively employed by the police, it is evident that we cannot learn much from it, since milk is a solution of substances specifically heavier than water, in which are suspended globules of cream specifically lighter than water; whence it of necessity follows that milk skimmed and diluted with water may have the same density as milk rich in cream and free from admixture of water.

In the task before me, I endeavored to settle these three points:

1st. Is the hydrometer fitted to give the density of milk with accuracy?

2d. Does the estimation of the density of skimmed milk make known the quantity of dissolved matter?

3d. Do the creamometer and the lactoscope indicate with accuracy the proportion of the fatty globules held in suspension?

In studying the first point I naturally had in view all the hydrometers of constant weight, without regard to the names they bear or the graduation with which they are provided. I have already stated that considered by themselves, and without a simultaneous determination of the proportion of the cream, the hydrometers do not give us much information as to the nature of fresh milk; but we must study to see if there are not still weightier reasons for regarding the use of hydrometers for milk as disadvantageous.

In the first place the coefficient of dilatation of milk is unknown; the tables which have been constructed in accordance with the experiments of certain observers, do not merit our confidence, from the fact that the ratio of the soluble matters varies greatly in different samples of milk. We are obliged, therefore, in using the hydrometer, to work invariably at one and the same temperature.

There is another circumstance which may cause the hydrometer to give very unreliable indications, especially if minute precautions are neglected. When a hydrometer is immersed in a liquid, and allowed to move freely, it sinks to a greater depth than that at which it will come to rest after a few oscillations, and at which its reading would be taken; this depth is moreover greater in proportion to the height above the point of equilibrium at which the instrument is let fall.

Therefore, since milk is a liquid more or less viscid, it is easy to see that the stem of the hydrometer being moistened by the milk retains a considerable quantity adhering to it, which renders the weight of the instrument very variable. Experiments which I have made in this connection show that very serious errors may result, sufficiently great to be equivalent to a difference of five per cent. more or less of water in the milk. It is moreover evident that these errors are greater the smaller the bulk of the hydrometer relatively to the diameter of the stem, so that with the small galactometer of A. Chevallier, which is so highly praised by Messrs. A. Chevallier and O. Reveil,* the errors would be larger than with the lactometers of large size generally used in this country [*i.e.*, in Holland].

By making comparative determinations of the density of different samples of milk by means of direct weighings, and by the use of either Chevallier's galac-

* Notice sur le lait. Paris, 1856.

tometer or of Geisler's hydrometer (which has a volume of about 50 c.c. and a stem measuring scarcely 3 mm. in diameter), I satisfied myself that the indications of these two instruments agreed very imperfectly with the results obtained by the first-named method. This applies to skimmed milk, and to a greater degree to fresh milk ; for the latter there is still another cause of error. Milk is actually a liquid heavier than water, in which lighter globules float with a tendency to come to the surface. We have then a case similar to that of a viscid liquid holding in confinement air-bubbles, which, by attaching themselves to the lower surface of the immersed body, necessarily vitiates to a certain extent the determination of the density. We will see presently that this error becomes much greater in the case of milk which has been violently agitated.

I found also that even in the case of skimmed milk, the specific gravity, though determined with great care, bears no fixed relation to the sum of the constituents held in solution; while as to fresh milk, that goes without saying. The density of the skimmed milk does not indicate the sum of substances held in solution, because the relative proportion of sugar, casein, extractive matter, and inorganic salts is not the same in different samples of milk.

Experiments have also shown that very little connection exists between the indications of the creamometer and the lactoscope, and the quantity of fatty matter contained in the milk which can be extracted by ether. It is moreover natural that this should be the case, especially as we have to deal with milk sent from a great distance and which has in consequence been subjected for a greater or shorter period to all kinds of vibrations and shocks.

Before going any further we must consider for a moment the churning of milk, in order to combat a common error with reference to what takes place in this operation. Most farmers think that butter sepa-

rates on churning only when the milk becomes acid; science teaches us, on the contrary, that sweet milk yields butter by churning as well as sour. It is also supposed that during the agitation of the milk with the air, the milk becomes sour, and the lactic acid found dissolves the membranous envelope of the milk globules, the contents of which are then free to collect as little lumps of butter. The following experiments show beyond a doubt that these views are incorrect.

The milk used in these experiments was drawn in the morning at half-past four o'clock, on a pasture in the neighborhood of Amsterdam, and the precaution was taken of holding the pail close up to the udder, in order to avoid as much as possible the formation of froth; this milk was brought in two pails into the laboratory, care being given to avoid agitation.

The milk had a neutral reaction, at least during the first seconds of the contact with test-paper; later the reaction was acid.*

We took several flasks, each having a capacity of two litres, and into each we poured one litre of milk. To one of these flasks we added several drops of lactic acid, so that the milk reacted acid at once. To the second flask no addition was made. To the third, several drops of a solution of potassium carbonate were added, until the milk had a weak alkaline reaction; in a short time, however, the reaction became acid, and immediately after churning it was neutral. Into a fourth flask we introduced a much larger quantity of potassium carbonate, such an amount that the milk remained alkaline after churning. The milk had a temperature of 21° C. These four flasks were shaken

* I think that for the examination of milk as to its action on test-paper, it is absolutely necessary to take into consideration the reaction which is observed in the very first moments, since it is well known that milk exposed in thin layers to air sours rapidly. It is probable that the widely differing reports of different observers of the reaction of milk should be attributed to this circumstance. E. H. von B.

by four persons with the same force, for one minute, and then allowed to rest. On the sides of each flask we saw granulations, a proof that the butter had begun to separate. Examined under the microscope these particles appeared like large fatty drops, of an irregular oval form, frequently like a mulberry in shape, and these drops flattened by pressure between two plates of glass. The flasks were shaken a minute longer. The particles deposited on the walls had increased to an equal extent, and the same took place each time the shaking was repeated. After ten minutes the particles had become of considerable size, and after eighteen minutes we found in each of the four flasks little buttery masses of a yellow color and the size of a pea; the separation of the butter, both as regards its quality and its quantity, took place in a very satisfactory manner. After the operation, as already stated, the milk had a neutral reaction in the third flask and an alkaline reaction in the fourth. No difference whatever was noticeable in the four flasks. The butter taken out of the flasks and examined under the microscope presented precisely the same aspect as that of the particles formed after the first minute's shaking.

In the milk deprived of the fatty matter, very small globules were seen in abundance, but the number of large globules had diminished considerably.

This experiment, which any one may repeat for himself, proves, as I think, that we must abandon the idea of a solution of the envelope of globules by means of the lactic acid formed, and strikes a blow at the very existence of these membranous envelopes of the fat-globules, the belief in which rests moreover on a very weak foundation.

The idea which I entertain of churning is as follows: By agitation the milk globules are thrown against each other with a certain force, and when the temperature is suitable, they remain adhering to each other,

and this gives rise to the mulberry-shaped lumps which compose the yellow butter desired. When the milk is too cold, every farmer knows that he can churn for hours without separating the butter, and hence he adds a little warm water. In this case the globules of the milk are too hard, even crystalline, and the aggregation cannot take place. On the other hand, what ensues when the milk is too warm, as happens in summer, or in winter after too much warm water has been added?

The butter is then *burnt*, as the farmers say; it forms small particles, does not easily collect in lumps, and yields a white mass, opaque, very soft, and which by exposure to cold becomes harder, but does not become yellow and translucent. This is because the fatty matter has been melted; the little drops unite to form larger drops, but they cannot yield lumps, because in the existing conditions churning produces an emulsion. In spite of all their efforts, it happens that the farmers do not succeed with the churning, and they attribute their want of success to all sorts of causes. The use of the thermometer would teach them to avoid these accidents. The temperature at which fine butter is obtained is fixed between very narrow limits; numerous experiments, in which I also used churns, have established this temperature between 20° and 22° C. By always working at this temperature, instead of adding warm water or cold water almost without care, the butter-maker will avoid many failures.

Besides the experiments just described I made two others: I took two flasks containing milk; to one I added sodium sulphate, and to the other sodium chloride in such quantity, that after shaking a moment some of the salt remained undissolved. After the milk, which had cooled down considerably, was brought to the temperature of 21° C., the two flasks were shaken as before during a specified number of

minutes; I found thus that the addition of the salts had no sensible influence on the separation of the butter.

A final experiment will show us clearly why the indications of the creamometer are of no value after the milk has been shaken, and why in consequence this instrument can be of no use in large cities where the milk is often transported several miles in wagons.

Creamometer No. 1 was filled with milk not shaken; No. 2, with milk which had been agitated one minute; No. 3, with milk which had been agitated two minutes, and so on. In the creamometers which contained milk agitated for a few minutes only, there formed after a short time a well defined layer of cream, which occupied 1 to 2 hundredths of the volume of the milk taken, and beneath this a second layer formed over night, having an entirely different aspect from the first layer. On the other hand, the milk which had been shaken ten minutes or more yielded, as soon as poured into the creamometers, small lumps which came to the surface, and occupied in one 2 to 3, in the other 11 to 12 hundredths of the capacity. In all the creamometers a second layer of cream formed on standing, and the longer the milk had been shaken the smaller was this layer. The indications of the creamometers were naturally very discordant, while that containing the milk not agitated marked $8\frac{1}{2}$, the other samples marked between 10 and 6.

From the foregoing it is evident in my opinion that a simple determination of the density of milk and of the amount of cream, by means of the creamometer or of the galactoscope, by no means enables us to judge with any degree of certainty of the amount of the sophistication, whether by skimming or by adding water. Such determinations can at best be used only for ascertaining an addition of water equivalent to 10, 20, 30, or 40 per cent., and a considerable removal of the cream; and in certain cases when the water em-

ployed to adulterate the milk is brackish, as is the case in Amsterdam, a knowledge of the density enlightens us still less on the composition of the liquid.

The principal reason which prevents recourse to complete analysis for determining the adulteration of milk lies in the circumstance that these analyses, to be of any service, require to be made in large numbers, and each requires much time and labor. The idea has, therefore, occurred to various chemists that it may suffice to estimate one of the constituents of the milk in a rapid and yet accurate manner, and to calculate from this determination the degree of sophistication to which the milk has been submitted.

Thus M. Marchand has constructed a *lactobutyrometer*, in which a given volume of milk mixed with a small quantity of a solution of sodium hydrate is agitated with an equal volume of ether, after which the same amount of alcohol is added, the whole is shaken again and gently warmed. The butter, he claims, is completely insoluble in this mixture, and collects on the surface in a layer the thickness of which can be read on the graduated tube.

Messrs. Reveil and Chevallier, starting with the idea that the proportion of lactose is sufficiently constant in milk, heat the milk to incipient ebullition, and add (as suggested by C. Struckman, *Chem. Pharm. Centralblatt*, 1855, p. 695) a few drops of acetic acid, thereby obtaining as they claim, and as confirmed by Mr. ter Kuile, a solution as limpid as water, in which the lactose is determined by Barreswil's method. I must say that I have tried this process many times, and although I have varied the quantity of acid added, and have tried acids of different kinds (acetic, sulphuric, hydrochloric, oxalic, tartaric), I have never succeeded in obtaining a limpid liquid.

Usually it is very turbid; in the most favorable cases it remained opalescent, but to such a degree that it

was impossible to estimate the sugar either by the copper solution or by the polariscope.

L. Ladé * recommends the estimation of the proportion of casein by means of a standard solution of mercurous nitrate; E. Monier † suggests the use of a standard solution of potassium permanganate for the same purpose.

But the question arises, is it possible to decide, from the estimation of one of the constituents of milk, what alterations this liquid has suffered? All experimenters have found the richness of milk in butter is very variable, even for the same cow, and the same may be said to obtain to a less degree of the substances dissolved in the milk.

The relative proportion of lactose and of casein shows marked variations in different samples of milk, as demonstrated by my investigations.

Judgment should not then be founded upon estimations of a single essential constituent of milk, but upon the estimations of several constituents. For the same reason, I also disapprove of employing exclusively the determination of the non-volatile substances in the milk, contrary to the opinion of many chemists, who see in this method a sure means of determining the dilution by water.

At the same time I consider this determination, combined with that of the fatty matter, and also (in doubtful cases) with that of the sugar and casein, as the only good method of testing milk.

Up to the present time, however, the estimation of the non-volatile constituents of milk has always been a very long operation, and accompanied with many difficulties, so that it was impossible to make a number of these determinations in a short time with the neces-

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* *Schweiz. Zeitschrift für Pharmacie*, reproduced in the Polyt. Centralblatt, 1852, 2d Sec.

† Comptes rendus, 1858, xlvi., p. 256. Journ. f. prakt. Chemie, 1858, p. 478.

sary accuracy. I believe that the method I am about to explain will effect a notable improvement in this respect.

It is well known that during the evaporation of milk (even when at a temperature below boiling, as on a water-bath), there forms on the surface a very firm pellicle, which prevents further evaporation; when this film is removed, a new one forms immediately, and so on.

This film is composed of casein penetrated with fatty matter. By constantly stirring and breaking the pellicles as fast as they form, it is possible to evaporate the milk to dryness, or rather apparently so, for the residue is not yet by any means free from water, and must then be dried at a temperature higher than 100° C. Most chemists advise using a temperature of 105° C.; if, however, it is desired to continue the desiccation until two successive weighings (each after drying one hour at 105° C.) show no loss, the residue is found to become colored of a dark brown, particularly at the edges, and it is almost impossible to obtain two equal weights on account of the great hygroscopicity of the brown substance formed (probably caramel). Dissolved in water, the residue yields a brown solution. It is evident, then, that the weight of the residue thus obtained does not express the sum of the solid constituents of the milk.

The method described by Mr. Haidlen, and which consists in adding to the milk to be dried one-fifth its weight of gypsum dried at 100° C., has indeed somewhat lessened the inconvenience named, but has not entirely removed it, and besides does not dispense with incessant agitation of the liquid during the whole duration of the evaporation—during, in fact, several hours.

Moreover, this method may occasionally give rise to serious errors, when the gypsum is not perfectly pure, or when it has not been dried with sufficient

care. If dried at too high a temperature, gypsum changes into anhydrite, which takes up water of crystallization as soon as it comes in contact with moisture. On this account Mr. Wicke has recommended the substitution of sulphate of barium for gypsum; the barytes, having been heated to redness and thus deprived of all traces of water, can be moistened and dried at 105° without changing in weight.

Instead of these two substances, C. Brunner* proposes the use of wood charcoal in coarse powder; but I must protest strongly against employing this material, since wood charcoal, as is well known, cannot be considered as a body indifferent in its behavior to organic substances.

All things considered, the best material to mix with the milk to facilitate evaporation is incontestably pure sand washed with hydrochloric acid, as suggested by Otto.

After having satisfied myself by repeated experiments that the determination of the fixed constituents of milk, by means of any of the foregoing processes, not only leaves much to be desired with respect to accuracy of the results, but also necessitates far too much labor ever to be employed in cases where hundreds of samples are to be tested. I conjectured that the desired ends might be attained by using a perfectly indifferent porous mass capable of absorbing a given amount of milk (not too small) without allowing the smallest loss by dripping from the porous material. The substance thus impregnated could be exposed to a current of dry air, at first at a moderate heat and afterwards at a temperature slightly above 100° C.† Owing to the extremely divided condition of the milk, no films could form to prevent the free passage of air through the porous mass after drying. The

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* Polyt. Journ., cxlvii., p. 132.

† Liebig's Annalen, April, 1857, p. 60.

increase in weight of this mass would give the sum of the fixed constituents of the milk. My first experiments to realize this idea were unsatisfactory.

Plaster tempered and solidified absorbed scarcely any milk, even when fragments of pumice-stone were mixed with it. Pumice-stone itself is too fragile to allow of handling it and drying the pieces without a small amount of powder becoming detached. Of various kinds of earthenware which I tried none were sufficiently porous. I then had little cups made with very thick sides of porous baked clay; but in this case again the porosity was insufficient, the cream remained in large measure on the surface, and formed by drying a layer impenetrable to air.

The most simple measure is often that one thought of last, and this was true in my own case. At length I found that sand well washed with hydrochloric acid, ignited strongly, and placed in a well-dried filter—not supported in a funnel, but freely suspended in such a manner that the whole surface of the paper is exposed to the air—that sand thus treated was, on account of its chemical inertness, the substance which suited best the object in view.

The little difficulties which were met with in practice were easily overcome, and I believe I can affirm that the method I devised for the analysis of milk is capable of extended application in chemistry, especially in physiological chemistry. In the latter branch of the science, difficulties of every kind oppose themselves when it is required to evaporate to dryness solutions of animal and vegetable substances; as, for instance, in the analysis of blood, of bile, of urine, etc.

Select sand which is quite white and clean; better yet would be colorless quartz in powder. Digest the sand with hydrochloric acid, wash well with rain-water at first and lastly with distilled water, until the latter yields no trace of acid. This may be prepared

on a large scale. Dry the sand, and ignite in a clean-covered Hessian crucible, and while still red hot pour the contents from a certain height upon a clean stone in order that the organic matter carbonized during the ignition may be burned while falling through the air. After cooling, place the sand in clean bottles previously dried, and cork well; thus the sand may be preserved for use.

The filter paper, cut in discs of 10 to 12 cm. in diameter, is also washed with hydrochloric acid and water, then dried in a current of dry air, raising the temperature at last to 110° C., and finally preserved in wide-mouthed bottles closed with rubber corks.

A disc of copper standing on feet 10 cm. in height (see Fig. 1) is pierced with ten, twelve, or a larger number of round holes having a diameter of 5 cm., and placed at a certain distance from each other. In these holes are hung rings made of glass rods, the diameter of the rings being 4 cm., and that of the rods 3 mm.; these rings rest on the copper disc by mean of little curved arms of glass soldered to them.

Subsequently I employed rings made of baked clay. In each of these rings is placed a filter folded in quarters in the usual manner, and filled with sand up to $\frac{1}{2}$ cm. of the edge: this step requires only a few minutes. Near each hole a number is scratched upon the copper disc; in the centre of the disc a wooden handle is fastened, by means of which the disc, with its load of sand-filled filters, can be handled with ease; the disc also has a small hole near the circumference, through which a thermometer is introduced.

The heating apparatus consists of a copper bath with double walls, between which is placed paraffin; in this air-bath one or two copper discs above described, and which I call *supports*, are inserted one above the other, as shown in the cut; A and B have each ten holes, so that twenty filters can be dried at one operation.

The cover of the bath fits closely, and carries at its centre a small tube, which is covered about with wood

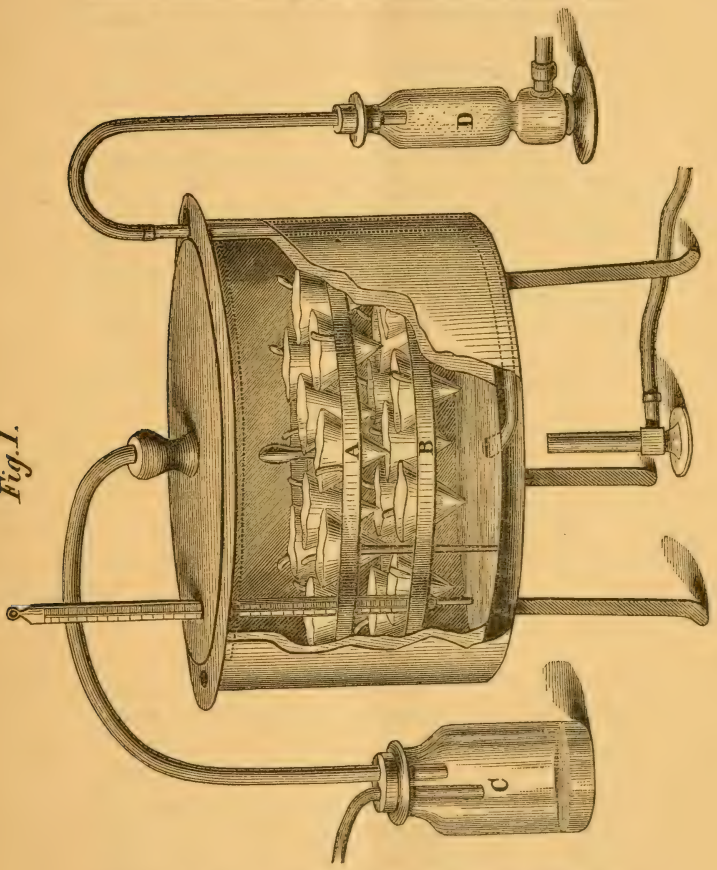

Fig. I.

and serves at the same time as a handle; this tube is connected with a Woulfe-bottle C, in which the water-gas condenses, and which is joined to a strong aspirator, such as I have described in the *Archives Neerlandaises*, vol. i., p. 191.

The cover is pierced with another opening, in which is fastened a thermometer; the bulb of this thermometer, passing through the holes in the *supports*, reaches to a level with the points of the lower filters. Between the double walls of the bath is fastened a copper tube, bent twice at right angles, and terminating at one end in the middle of the air-bath, while the other end is connected, at the close of the operation, with an apparatus for drying the air over sulphuric acid or calcium chloride.

As many glass flasks and funnels are required as there are analyses to be executed; the capacity of each flask is exactly 100 c.c., as indicated by marks on the necks; the funnels (Fig. 2) have their edges ground

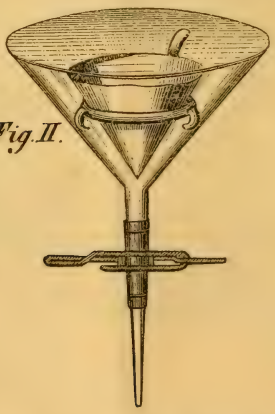

Fig. II.

with emery and are covered with watch-glasses. All are carefully numbered. The funnels are of such a size that the filters hang freely when placed on the rings of glass, and after covering the funnels a space of $\frac{1}{2}$ cm. remains between the upper edge of the filter and the glass cover; to the stem of each funnel is attached a caoutchouc tube, closed with a spring-clamp.

Finally, as many desiccators are required as there are

analyses to be made, for it is not safe to use a common desiccator for substances as hygroscopic as the fixed solids in milk. I use as a desiccator or receiver a beaker glass, in which is placed a triangle for supporting the rings with their curved arms above described. At the bottom of the glass is placed calcium chloride, and the whole is covered and closed with a hood of india-rubber.

The milk analysis is conducted as follows: Having filled the filters with sand, place them on the support and heat them for half an hour in the air-bath at 110° C.; after cooling them in the desiccators, weigh them, successively placing them on a small beaker glass, from which the bottom has been cut and the edges of which have been ground (Fig. 3).

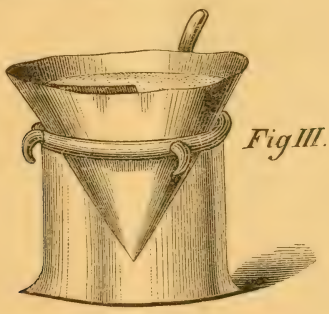

Fig III.

In my experiments the beaker glasses with glass rings and sand-filled filters weighed from 68 to 75 grammes. Having completed the weighings, take 10 c.c. of milk with a pipette from each of the samples, the temperature of which has previously been brought to 15° C., and add the milk to one of the filters, taking care to moisten the whole surface of the sand, save the exterior edge.

The sand on the filter can absorb more than 10 c.c. of milk without the point of the filter becoming moistened; on some occasions a few drops of liquid

ran from the point of a filter, but this was when I had to deal with milk adulterated with an equal volume of water. In case this happens, the filter is replaced by another, to which only 5 c.c. of milk are added; then, after the filters are nearly dry, the other 5 c.c. are added and the desiccation continued. In making analyses, I continually worked with 10 c.c. of milk, and I calculated the results as parts in a thousand by volume—that is to say, in a litre. I think this method of procedure is more rational than to give the composition in hundred parts by weight, when we consider that milk is sold by measure, and not by weight.

When all the filters have been charged with milk, the support is placed in the air-bath and the temperature is raised to about 60° or 70° C., which heat is maintained so long as the current of air which passes through the apparatus deposits moisture in the Woulfe-bottle. After this the aspiration is moderated, and air previously dried is passed through the apparatus, which is then heated to 105° C. for a good half-hour. The desiccation is entirely completed in 4 to 5 hours, without the necessity of giving it any attention, save to examine from time to time the stand of the thermometer. The filters are then allowed to cool one hour in the receivers, and weighed again. The difference between the first and second weighings gives the sum of the fixed constituents of the milk. For greater precaution, the support may be replaced in the air-bath and heated an hour longer at 105° C., again cooled and weighed, in order to make sure of complete desiccation; but if the process described has been followed closely, it will always be found that the second weighing differs from the first by only 1 (or at most 2) milligrammes, more or less. Care must be taken not to remove the filters too soon from the receivers, since sand cools very slowly.

It is also of the greatest importance to avoid a higher temperature than 70° C. during the evaporation

and before the filters are dry, since if wet filters are heated suddenly to 100° C., their edges become immediately of a brownish yellow color; but by effecting the drying at a low temperature this does not occur. When the mass is once dry, it sustains a heat of 105° C. without browning. Otto has pointed out this fact previously.

As an example, I produce the results of an examination of asses' milk, collected in a stable at Amsterdam, and analyzed for the purpose of testing the accuracy of the method.

Three sand-filters, dried, weighed:

No. 1.....74.883 grammes.
No. 2.....71.577 "
No. 3.....71.338 "

Each was charged with 10 c.c. of milk, and dried, and weighed again; this gave:

No. 1....75.981, and consequently 1.098 fixed solids.
No. 2....72.672, " " 1.095 " "
No. 3....72.438, " " 1.100 " "

After drying the filters an hour longer in the air bath and cooling, the following figures were obtained:

No. 1.....75.980 grms.
No. 2.....72.672 "
No. 3.....72.438 "

It is evident that the second drying was not necessary.

To determine the proportion of fat, we proceed as follows: The filters with contents are placed in the funnels, which are filled with anhydrous ether and closed for half an hour; the ether is then drawn off by opening the pinch-cocks, and the operation repeated twice; the filters are washed twice more with ether and placed on the *support*, which is then introduced into the air-bath. Each filter requires scarcely 100 c.c. of ether. If the desiccation has been carefully made the ether runs off as colorless and as limpid as water.

Nos. 1 and 2 were thus treated, then dried and cooled as before; this requires very little time. The weighings gave:

No. 1...75.775 grms., or a loss of 0.206
No. 2...72.460 " " " 0.212

The filters were washed again with 100 c.c. of ether to each, dried, cooled, and weighed again; this gave:

No. 1.....75.775 grms.
No. 2.....72.460 "

The first treatment with ether had dissolved all the fat.

Some chemists recommend to evaporate the ethereal solution in weighed capsules, to dry the residue at 100° C., and to weigh it. I do not advise this method, partly because a loss results by the ethereal solutions creeping over the sides of the capsules, and partly because I have found that fat dried in this manner at 100° C. partially evaporates, as is shown by the odor and the rise of white vapors.

For the determination of the sugar we proceed in the same manner as with the fat, substituting, however, warm water for ether; the water which filters through as collected in the 100 c.c. flasks above mentioned. By using 90 c.c. of water in successive portions the sugar is completely extracted. Since, however, casein is not entirely insoluble in cold and hot water, the filters lose weight by a second treatment with warm water; the second filtrate does not contain sugar, according to my experiments.

Nos. 1 and 2 treated in this way, dried and cooled, gave on weighing

No. 1....75.035 grms., or a loss of .740
No. 2....71.730 " " " .730

After being again treated with 100 c.c. of warm water, dried and cooled:

No. 1...75.011 grms., or a loss of 0.764
No. 2...71.714 " " " 0.746

By a third treatment we obtained:

No. 1...75.004 grms., or a loss of 0.771
No. 2...71.700 " " " 0.760

When the desiccation has been properly conducted, the water solutions are quite colorless and clear.

The aqueous solution first obtained was cooled to 15° C. in the graduated flask in which it was collected, diluted to 100° C., and in this the sugar was estimated by means of Mulder's standard solution.

10 c.c. of the test solution, diluted with 10 c.c. of water, required:

No. 1...5.25 and 5.30 of sugar solution.
No. 2...5.35 " 5.30 " "

The second filtrate obtained above was added to 5 c.c. of the standard solution, and on first boiling no reduction took place; but by continuing the ebullition a very slight one ensued—so weak, however, that after adding all the filtrates of the first and second treatment, making 400 c.c. in all, the liquid remained of a dark blue color. The reduction observed may be ascribed to the casein, which by prolonged boiling reduces a small quantity of the copper solution.

A creamometric determination of the asses' milk was also made, giving 3 per cent. by volume. The galactometer marked 110 on the yellow scale in the milk in its natural state, and 107 on the blue scale after skimming.

As in all my analyses, I also estimated the ashes of the milk, by placing 10 c.c. of milk in a platinum crucible, adding several drops of acetic acid (to prevent the formation of films and to hasten the evaporation), and evaporating on the water-bath, igniting to a white heat, and weighing. This gave 0.0355 grms. of ashes.

The analysis of asses' milk, which I have merely taken as an example in order to show the accuracy of the method, yields the following figures in a litre;

Fat	20.9	grammes.
Milk sugar	61.5	"
Other substances soluble in water.	12.0	"
Substances insoluble in water	15.3	"
Mineral matter	3.5	"

Since milk is a mixture of various non-volatile substances and water, and no constant proportion by weight exists between the constituents, the only way to determine its average composition is by the analysis of a large number of samples of pure milk, collected from different localities and from animals placed in varying conditions and submitted to different nourishment.

In my memoir, *Over de keuring der koemelk en over de melk in Nederland*,* I published the composition of a large number of specimens of cows' milk received from different parts of the country, and which represented not only milk in a state of purity, but also milk as delivered to the inhabitants of cities.

In Table I., I have collected the twenty samples which were sent to me as coming direct from the cow, though I cannot affirm that they express the exact composition of veritable milk, since I do not know whether the whole of the milk was drawn from the cows' bags; for it is well known that the milk drawn towards the last is richer in butter than that obtained at the beginning.

These twenty samples are of winter milk, and are consequently derived from animals fed in stables. The following particulars were given me with regard to some of them:

No. 1.—Milk of a cow which had calved three weeks previously, and fed on hay and linseed cake.

No. 3.—Milk of a cow which had calved four times, the last time January 17th (three weeks previous to the analysis of the milk). Food: hay, linseed cakes, and carrots.

* *Verslagen en Mededeelingen der Koninklijke Akademie der Wetenschappen*, Section des Sciences phys., t. viii., p. 145.

TABLE I.

	On 1000 c.c. of Milk.						On 100 Parts by Weight of Non-volatile Matter Deprived of Fat.				Determination of Density by Direct Weighing.		Lacto-meter.		Galacto-meter.		Cream-ometer.
	Non-volatile substances.	Substances soluble in ether.	Sugar.	Other substances soluble in water.	Substances insoluble in water.	Mineral constituents.	Milk-sugar.	Other substances soluble in water.	Substances insoluble in water.	Mineral constituents.	In its natural state.	Skimmed.	In its natural state.	Skimmed.	In its natural state.	Skimmed.	
1. 11 March, near Amsterdam.	123.8	26.8	45.8	12.0	39.2	7.9	47	12	41	8.1	1.0343	1.0360	16.3	17.0	120	113	10.0
2. 11 March, near Leyden....	111.4	25.7	47.0	11.6	27.1	7.6	54	14	32	8.9	1.0320	1.0328	15.2	15.6	110	106	7.7
3. 4 February, near the Hague	135.6	35.3	39.1	14.4	44.8	7.7	40	13	46	7.8	1.0353	1.0369	16.7	17.5	124	116	10.0
4. 25 March, at Papendrecht..	108.4	19.7	47.4	11.3	30.0	7.0	53	13	34	7.9	1.0310	1.0320	14.7	15.2	111	102	8.7
5. 25 March, at Dubbeldam...	123.9	33.1	35.5	20.3	35.0	6.8	39	22	39	7.5	1.0303	—	14.4	—	106	—	8.5
6. 15 April, near Utrecht.....	121.6	23.7	40.9	14.9	42.1	8.0	42	15	43	8.1	1.0319	1.0340	15.0	16.0	111	109	9.5
7. 15 April, near Utrecht.....	112.1	23.3	45.5	12.0	31.3	7.2	51	13	36	8.0	1.0307	1.0330	14.5	15.6	106	105	10.7
8. 9 January, near Arnhem...	125.5	32.3	52.8		40.4	7.5	56		44	8.0	1.0338	1.0340	—	—	124	—	4.7
9. 7 January, near Tiel.....	110.4	27.7	59.3		23.4	7.0	71		29	8.4	1.0309	1.0329	—	—	—	—	9.2
10. 7 January, near Tiel.....	105.0	29.8	52.0		23.2	6.4	69		31	8.5	1.0280	1.0290	—	—	—	—	8.5
11. 7 January, near Doesburg..	124.9	20.8	54.8		49.3	6.7	53		47	6.4	1.0318	1.0336	—	—	—	—	12.5
12. 9 January, near Zutphen...	123.6	37.1	51.1		35.4	7.9	59		41	9.1	1.0325	1.0341	—	—	119	—	8.0
13. 9 January, near Zutphen...	107.1	25.5	51.3		30.3	7.1	63		37	8.6	1.0307	1.0312	—	—	112	—	7.2
14. 7 January, near Niméguen.	137.4	43.4	60.7		33.3	7.4	64		36	7.9	1.0341	1.0363	—	—	—	—	—
15. 7 January, near Niméguen.	125.8	39.9	57.8		28.1	7.5	67		33	8.7	1.0326	1.0348	—	—	—	—	8.5
16. 7 January, near Niméguen.	104.4	20.9	59.4		24.1	7.3	71		29	8.7	1.0321	1.0333	—	—	—	—	7.7
17. 28 April, near Leeuwarden..	112.6	27.6	41.4	19.5	24.1	7.0	48	22	30	8.2	1.0303	—	—	—	—	—	8.7
18. 28 April, near Leeuwarden..	116.4	22.8	39.5	16.3	37.8	7.2	42	17	41	7.6	1.0300	—	—	—	—	—	8.5
19. 28 April, near Leeuwarden..	118.8	27.7	40.9	20.8	29.4	7.1	45	22	33	7.8	1.0301	—	—	—	—	—	—
20. 28 April, near Leeuwarden..	122.4	27.7	43.0	20.3	31.4	7.3	45	21	34	7.7	1.0318	—	—	—	—	—	3.5
Mean.....	118.5	28.5	57.0		33.0	7.3	63.2		36.8	8.1	1.0318	1.0334	—	—	—	—	—

No. 6.—Mixture of milk of eight cows, drawn in the morning. Food: hay, potato-parings, malt, and linseed cakes.

No. 7.—Mixture of milk of seven cows. Food: hay, linseed cake, and carrots.

No. 8.—Milk of a cow, drawn at noon. Food: hay and turnips.

No. 9.—Milk of a cow milked at 7 A.M. Food turnips, chopped straw, and horse-beans.

No. 10.—Milk drawn at 8 A.M. Food: hay only.

No. 11.—Mixture of milk of four cows, milked at 7 A.M. The cows received daily (for all four) 3 kilos cakes of rape seed, 6 kilos of black bread, 8 kilos of bran and chaff from wheat flour, 12 litres of small potatoes, 12 beets, besides hay and straw.

No. 12.—Milk drawn at 7 A.M. Food: straw, hay, turnip-tops, and a warm feed made of potatoes and turnips cut in pieces, cooked, and mixed with colza cakes.

No. 13.—Milk drawn at 7 A.M. Food: hay in abundance, a little straw, beets and turnips mashed and mixed with colza cakes.

No. 14.—Milk drawn at noon, the time of "mulsion" being at 6 A.M., noon, and 6 P.M. The cow had calved five weeks previously. The food consisted chiefly of hay, turnips, and a few linseed cakes; she received also, however, kitchen refuse, such as potato-parings, cabbage-leaves, etc. It is to be noticed that the cream would not rise in the creamometer.

No. 15.—Milk drawn at 8 P.M.; time of "mulsion," $6\frac{1}{2}$ A.M., 1 P.M., and 8 P.M. The cow had calved four weeks previously. The food consisted of hay, carrots, turnips, half a colza cake daily, potato-parings and other kitchen refuse, and material from a steam distillery of potato brandy.

No. 16.—Milk drawn at 7 A.M.; time of "mulsion," 7 A.M., noon, and 6 P.M. The cow had

calved towards the end of November. The food consisted of hay, oats and oat-straw, half a colza cake, and beets.

No. 17.—Evening milk, and No. 18 morning milk of the same cow, that one yielding the *most* milk of any in the stable. Food: hay.

No. 19.—Evening milk, and No. 20 morning milk of the same cow, which was regarded as giving the *best* milk; also fed on hay exclusively.

To obtain still more certain data on the mean composition of milk, the milk of five cows, forming part of a dairy of Onderkerk, near Amsterdam, was examined during a period of ten consecutive months, from the moment of calving (which took place in winter) until the month of October following, when they were taken back to the stable.

The food supplied consisted of hay and linseed cakes in the stable, and grass in the pasture. In the stable they were milked at 5 A.M. and 4 P.M.; in the pasture, at 3 A.M. and 4 P.M. Care was taken to secure the whole supply of the "mulsion." The evening milk and morning milk were examined separately.

The five cows of which the milk was studied were:

A, aged 4 years; had calved thrice.
B, " 6 " " four times.
C, " 4½ " " three "
D, " 4 " " twice.
E, " 4½ " " three times; this cow fell sick in June, and was replaced by another.

F, aged 9 years, and which had calved for the ninth time in the month of May.

The second table gives the composition of the first milk secreted, the colostrum. During these three or four days the cows were milked three times in twenty-four hours. Table III. embraces the composition of the normal milk from the first week succeeding birth.

The low figures for the non-volatile substances in the milk of the nine-year-old cow are very striking.

TABLE II.

COLOSTRUM OF THE COW A.

Date.	Non-volatile substances.	Fat.	Ashes.
10 December, 1858. .	2.885	0.771	0.123
" " " . . .	1.810	0.580	0.117
" " " . . .	1.398	0.302	0.103
11 " " . . .	1.606	0.564	0.096
" " " . . .	1.501	0.435	0.087
" " " . . .	1.518	0.507	0.089
12 " " . . .	1.472	0.497	0.090
" " " . . .	1.491	0.486	0.089
13 " " . . .	1.387	0.451	0.082
COLOSTRUM OF THE COW B.			
8 January, 1859.	2.059	0.226	—
" " "	1.461	0.132	0.104
" " "	1.395	0.185	0.090
9 " "	1.310	0.127	0.090
COLOSTRUM OF THE COW C.			
14 January, 1859. . . .	2.899	0.585	0.098
" " "	2.178	0.422	0.100
" " "	1.630	0.369	0.090
15 " "	1.262	0.304	0.089
" " "	1.298	0.352	0.085
" " "	1.368	0.343	0.084
16 " "	1.259	0.299	0.084
" " "	1.218	0.257	0.083
17 " "	1.228	0.259	0.080
" " "	1.232	0.249	0.080
COLOSTRUM OF THE COW D.			
11 March, 1859.	2.370	0.330	0.100
12 " "	1.428	0.268	0.087
" " "	1.472	0.294	0.080
13 " "	1.216	0.308	0.080
14 " "	0.209	0.329	0.076
COLOSTRUM OF THE COW E.			
17 April, 1859.	2.798	0.280	0.106
18 " "	1.959	0.285	0.092
" " "	1.818	0.312	0.084
19 " "	1.468	0.444	0.080
" " "	1.389	0.461	0.076

TABLE III.

COW A. IN THE STABLE.

1858.	Non-volatile Matter.		Fat.		Mineral Constituents.		Lactoscope.		Lactometer.		Creamometer.	
	Morning.	Evening.	Morning.	Evening.	Morning.	Evening.	Morning.	Evening.	Morning.	Evening.	Morning.	Evening.
December 17.....	1.323	1.241	0.430	0.328	0.093	0.090	—	—	—	—	—	—
1859.												
January 10.....	1.115	1.048	0.300	0.213	0.082	0.076	—	—	—	—	—	—
" 19.....	1.111	1.127	0.279	0.281	0.071	0.070	—	—	—	—	—	—
" 28.....	1.128	1.126	0.265	0.260	0.070	0.071	—	—	—	—	—	—
February 12.....	1.174	1.182	0.258	0.255	0.070	0.071	—	—	—	—	—	—
" 26.....	1.144	1.128	0.243	0.249	0.072	0.072	—	—	—	—	—	—
March 10.....	1.200	1.195	0.275	0.265	—	0.071	—	—	—	—	—	—
" 24.....	1.187	1.205	0.254	0.271	0.072	0.071	—	—	—	—	—	—
April 8....	1.182	1.174	0.261	0.252	0.076	0.071	—	—	—	—	—	—
" 30.....	1.175	1.205	0.250	0.287	0.069	0.080	29	24	14.8	15.0	8	10
May 12.....	1.187	1.176	0.249	0.241	0.071	0.076	26	24	14.9	14.9	10	11
" 24.....	1.168	—	0.242	—	0.070	—	23	—	15.1	—	11	—
June 8.....	—	1.170	—	0.244	—	0.069	—	26	—	15.2	—	11
" 20.....	1.145	1.148	0.214	0.230	0.070	0.070	28	24	14.6	14.8	10	11
July 2.....	1.139	1.148	0.235	0.237	0.071	0.071	30	30	14.6	14.6	10	10
" 20.....	1.129	1.135	0.240	0.229	—	—	32	29	14.4	14.6	10	10

TABLE III.—*Continued.*

IN THE PASTURE.

1858.	Non-volatile Matter.		Fat.		Mineral Constituents.		Lactoscope.		Lactometer.		Creamometer.	
	Morning.	Evening.	Morning.	Evening.	Morning.	Evening.	Morning.	Evening.	Morning.	Evening.	Morning.	Evening.
August 15.....	1.150	1.143	0.247	0.238	—	—	31	30	15	15	9	12
September 1.....	1.139	1.150	0.240	0.248	—	—	30	31	14.6	15	9	9
" 18.....	1.195	1.222	0.284	0.309	—	—	28	28	15	15.1	11	10
October 4.....	1.274	1.280	0.310	0.303	—	—	28	28	14.9	14.9	10	10
" 21.....	1.276	1.288	0.305	0.311	—	—	29	28	15.1	15	11	10
COW B. IN THE STABLE.												
January 19.....	1.259	1.284	0.330	0.370	0.080	0.076	—	—	—	—	—	—
" 28.....	1.275	1.266	0.287	0.302	0.071	0.072	—	—	—	—	—	—
February 12.....	1.178	1.184	0.249	0.275	0.070	0.069	—	—	—	—	—	—
" 26.....	1.165	1.159	0.243	0.243	0.068	0.069	—	—	—	—	—	—
March 10.....	1.148	1.146	0.243	0.242	0.069	0.070	—	—	—	—	—	—
" 24.....	1.136	1.135	0.239	0.241	0.070	0.070	—	—	—	—	—	—
April 8.....	1.153	1.152	0.244	0.244	0.071	0.072	—	—	—	—	—	—
" 30.....	1.152	1.165	0.247	0.249	0.071	0.069	29	28	15	15	10	9

IN THE PASTURE.

May	24.....	1.194	1.194	0.260	0.279	0.071	0.071	30	29	14.5	14.5	9	9
June	8.....	1.245	1.263	0.263	0.273	0.069	0.070	31	29	15	15	8	10
"	20.....	1.205	1.275	0.263	0.280	—	—	28	31	15.2	15	10	8
July	2.....	1.193	1.200	0.284	0.280	—	—	—	—	—	—	—	—
"	20. ..	1.170	1.168	0.260	0.271	—	—	30	31	15	15	11	11
August	15.....	1.140	1.155	0 239	0.248	—	—	30	30	15	14.8	9	9
September	1.....	1.143	1.153	0.238	0.242	—	—	30	32	14.8	15	11	10
"	18.....	1.142	1.150	0.234	0.242	—	—	30	30	14.2	14.6	11	10
October	4.....	1.129	1.145	0.249	0.249	—	—	31	30	15	14.9	9	8
"	21.....	1.153	1.144	0.253	0.259	—	—	30	30	14.6	15	9	10

COW C. IN THE STABLE.

January	28.....	1.118	1.140	0.203	0.229	0.079	0.076	—	—	—	—	—	—
February	12.....	1.159	1.145	0.231	0.240	0.078	0.080	—	—	—	—	—	—
"	20.....	1.043	1.100	0.203	0.208	0.081	0.076	—	—	—	—	—	—
March	10.....	1.093	1.118	0.201	0.239	0.076	0.071	—	—	—	—	—	—
"	24.....	1.142	1.153	0.240	0.292	0.072	0.073	—	—	—	—	—	—
April	8.....	1.203	1.208	0.318	0.382	0.071	0.070	—	—	—	—	—	—
"	30.....	1.295	1.279	0.382	0.389	0.071	0.070	24	21	15.2	15.4	13	12

TABLE III.—*Continued.*

IN THE PASTURE.

1858.		Non-volatile Matter.		Fat.		Mineral Constituents.		Lactoscope.		Lactometer.		Creamometer.	
		Morning.	Evening.	Morning.	Evening.	Morning.	Evening.	Morning.	Evening.	Morning.	Evening.	Morning.	Evening.
May	12.....	1.196	1.193	0.379	0.385	0.069	0.071	24	24	15.6	15.1	10	11
"	24.....	1.183	—	0.348	—	0.72	—	21	—	15	—	10	—
June	8....	—	1.193	—	0.344	—	0.070	—	27	—	14.9	—	9
"	20.....	1.184	1.191	0.302	0.299	—	—	26	26	15.1	14.9	10	9
July	2.....	1.185	1.179	0.276	0.288	—	—	29	27	15	15.2	9	9
"	20.....	1.178	1.183	0.299	0.299	—	—	26	29	15	15.4	8	11
August	15.....	1.221	1.260	0.293	0.329	—	—	29	27	14.9	15	8	10
September	1.....	1.271	1.279	0.359	0.368	—	—	26	27	15.1	15	10	8
"	18.....	1.296	1.279	0.390	0.402	—	—	24	24	14.9	14.9	11	12
October	4.....	1.269	1.259	0.382	0.411	—	—	26	24	15.1	14.6	10	12
"	21.....	1.244	1.270	0.390	0.410	—	—	24	23	14.8	14.6	13	13
		COW D. IN THE STABLE.											
March	24.....	1.246	1.270	0.294	0.348	0.071	0.070	—	—	—	—	—	—
April	8.....	1.235	1.268	0.380	0.389	0.071	0.070	—	—	—	—	—	—
"	30.....	1.205	1.245	0.381	0.405	0.071	0.070	38	31	15	15.7	—	6

IN THE PASTURE.

May	12.....	1.198	1.195	0.399	0.419	0.071	0.069	26	24	14.9	14.6	8	10
"	24.....	1.238	1.202	0.408	0.378	0.069	0.071	24	27	14.2	14.7	8	7
June	8.....	1.175	1.168	0.343	0.318	0.071	0.070	30	31	15	14.9	8	6
"	20.....	1.140	1.128	0.242	0.289	—	—	31	34	14.9	14.6	10	6
July	2. ..	1.106	1.162	0.316	0.321	—	—	24	30	14.9	14.6	11	11
"	20.....	1.160	1.168	0.403	0.400	—	—	30	30	15	14.1	13	15
August	15.....	1.141	1.175	0.340	0.418	—	—	32	29	15	14.6	9	11
September	1... .	1.191	1.200	0.469	0.465	—	—	23	24	15	14.6	11	10
"	18.....	1.172	1.185	0.395	0 365	—	—	28	30	15.1	14.9	9	11
October	4.....	1.249	1.260	0.417	0.444	—	—	29	24	14.6	15.1	9	13
"	21.....	1.260	1.250	0.415	0.399	—	—	26	24	14.9	15	11	10

COW E. IN THE STABLE.

April	30.....	1.119	1.161	0.215	0.242	0.069	0.070	34	34	15	15	7	6

IN THE PASTURE.

May	12.....	1.178	1.172	0.295	0.290	0.069	0.070	30	29	15	15	8	10
"	24.....	1.216	1.235	0.315	0.320	0.068	0.070	27	30	15	14.9	11	11
June	8.....	1.248	1.257	0.299	0.313	0.070	0.070	74	30	15.1	14.9	6	7

TABLE III.—*Continued.*

COW F. IN THE PASTURE.

1858.	Non-volatile Matter.		Fat.		Mineral Constituents.		Lactoscope.		Lactometer.		Creamometer.	
	Morning.	Evening.	Morning.	Evening.	Morning.	Evening.	Morning.	Evening.	Morning.	Evening.	Morning.	Evening.
June 20.....	1.018	1.048	0.210	0.208	—	—	38	37	14	14.5	4	5
July 2.....	1.023	1.078	0.210	0.212	—	—	37	32	14.5	14.7	5	8
" 20.....	1.012	1.035	0.203	0.213	—	—	31	37	14.2	15	7	5
August 15.....	1.072	1.069	0.260	0.253	—	—	36	33	15	15	9	10
September 1.....	1.029	1.030	0.240	0.260	—	—	34	31	15	15	9	9
" 18.....	1.042	1.071	0.203	0.217	—	—	32	34	14.6	14.9	6	6
October 4.....	1.039	1.072	0.229	0.244	—	—	37	36	15	15	6	10
" 21.....	1.105	1.125	0.293	0.240	—	—	30	30	14.9	15	9	9

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